NON-PROVISIONAL APPLICATION FOR UNITED STATES PATENT

FOR

THERMAL MANAGEMENT OF PROJECTION APPARATUS

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THERMAL MANAGEMENT OF PROJECTION APPARATUS

BACKGROUND

Historically, projection engines of projection systems have been designed employing high intensity discharge lamps. These prior art projection engines/systems suffer from a number of disadvantages. For examples, the lamps typically have relatively short lives, and reduced brightness after an initial period of usage. Further, there is an appreciable period of waiting for the lamp to warm up, when a projection engine/system is first turned on. During that period, either no image is available or the available images are of poor quality.

Resultantly, there has been a lot of interest in developing and manufacturing in a mass scale projection engines and projection systems employing solid state light sources. Such engines/systems typically have the aforementioned disadvantages in a lesser degree. However, the issues still have to be addressed.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be described by way of the accompanying drawings in which like references denote similar elements, and in which:

Figure 1 illustrates a block diagram view of a projection engine/system in accordance with one embodiment of the present invention;

Figure 2 illustrates a block diagram view of another projection engine/system in accordance with another embodiment of the present invention; and

Figure 3 illustrates a block diagram view of yet another projection engine/system in accordance with yet another embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments of the present invention include but are not limited to thermally managed projection engines and projection systems.

In the following description, various aspects of embodiments of the present invention will be described. However, it will be apparent to those skilled in the art that other embodiments may be practiced with only some or all of the described aspects. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the embodiments. However, it will be apparent to one skilled in the art that other embodiments may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the description.

Various operations will be described as multiple discrete operations in turn, in a manner that is most helpful in understanding the embodiments, however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment, however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

Figure 1 illustrates a block diagram view of a projection engine (which may be a portion of a projection system) **100** in accordance with one embodiment of the present invention. As illustrated, for the embodiment, projection engine/system **100** includes light sources **102**, light valve **104**, projection lens **106**, optically coupled to each other as shown. Additionally, for the embodiment, projection engine/system **100** includes sensors **112** and active cooling arrangement **116** thermally coupled to light sources **102**,

as shown. Further, for the embodiment, projection engine/system **100** includes processor, electrically coupled to light sources **102** and light valve **104** as shown, and thermal management controller **114**, electrically coupled to sensors **112** and active cooling arrangement **116** as shown.

Light sources **102** are employed to provide a number of primary color light bundles. In various embodiments, the primary color light bundles comprise a red, a blue and a green light bundle. In alternate embodiments, other primary color light bundles may be provided instead.

In various embodiments, light sources **102** comprise solid state light sources. More specifically, in some embodiments, light sources **102** comprise light emitting diodes (LED), whereas in other embodiments, light sources **102** comprise laser diodes.

Light valve **104** is employed to selectively direct the primary color light bundles to projection lens **106**. A wide range of light valves, including but are not limited digital micro-mirror devices, may be employed to implement these elements.

Projection lens **106** project the focused primary color light bundles onto a surface. Likewise, a wide range of projection lens may be employed to implement projection lens **106**.

Sensors **112** are employed to monitor one or more thermal conditions of one or more regions or locations of one or more of light sources **102**. In various embodiments, sensors **112** are external, but proximally disposed to the regions/locations they monitor. In other embodiments, e.g. where light sources **102** are solid state light sources, sensors **112** are integrated with the light sources at the regions/locations of interest. Typically, but not necessarily, they are integrated to monitor the thermal conditions of a number of critical junctions of the solid state light sources.

Sensors **112** are designed to output signals that are indicative of the thermal conditions of the corresponding regions/locations they monitor. In various

embodiments, the output signals may be analog signals, and analog to digital converters may be employed to convert the signals to digital signals.

Active cooling arrangement **116** is employed to actively cool light sources **102**. In various embodiments, active cooling arrangement **116** may be a fan capable of operating at various speeds to provide various rates of air flow to cool light sources **102**. In other embodiments, active cooling arrangement **116** may be a TE (thermoelectric) cooler capable of operating at various levels to provide various rates of heat removal to cool light sources **102**. In yet other embodiments, active cooling arrangement **116** may be a liquid cooling arrangement with pipes and pump capable of operating at various levels to provide various rates of fluid flow to cool light sources **102**.

Thermal management controller **114** is employed to control the operation of active cooling arrangement **116** based at least in part on the signals outputted by sensors **112**. In general, thermal management controller **114** is designed to cause active cooling arrangement **116** to impart more cooling on light sources **102** when the thermal condition of light sources exceeds an upper end operational threshold, and to impart less cooling light sources **102** when the thermal condition of light sources is under a lower end operational threshold. In various embodiments, additional thresholds may be employed to further increase or decrease cooling levels as the sensors indicate the current operating state being further from the desired set point.

In various embodiments, the thresholds and response may be designed to achieve one or more of a number of system objectives. These system objectives may include but are not limited to extending the operational life of solid state light sources, reducing system acoustics, increasing or maximizing brightness and so forth.

The thresholds and response are application dependent, i.e. dependent on the thermal characteristics of the light sources and the cooling capability of the active

cooling arrangement. The thresholds and response for a particular combination of light sources and active cooling arrangement may be empirically determined.

Still referring to **Fig. 1**, processor **108** is employed to control light sources **102** and light valve **104**, to project images based on the pixel data of the images received. In some embodiments, the pixel data may be provided e.g. from an external computing/media device or an integrated TV tuner (through e.g. an input interface). A wide range of general or special purpose processors may be employed to implement processor **108**.

In various embodiments, processor **108** and thermal management controller **114** may be combined.

In various embodiments, projection system **100** is a projector. In other embodiments, projection system **100** is a projection television.

Figure 2 illustrates a block diagram view of another projection engine/system in accordance with another embodiment of the present invention. Similar to engine/system **100**, engine/system **200** comprises light sources **102**, light valve **104** and projection lens **106** optically coupled to each other, and sensors **112** thermally coupled to the light sources **102**, as earlier described. Likewise, engine/system **200** comprises thermal management controller **124** and processor **108** electrically coupled to sensor **112** and light sources/valve **102/104**.

However, unlike thermal management controller **114** of engine/system **100**, thermal management controller **124** of engine/system **200** is electrically coupled to the drive circuitry of light sources **102**. Further, thermal management controller **124** is designed to manage the thermal condition of light sources **102** by causing the drive circuitry of light sources **102** to vary the amounts of voltage or current it applies to drive light sources **102**. In various embodiments, thermal management controller **124** may

indicate to the drive circuitry of light sources **102** the amount of voltage or current the drive circuitry should vary.

As the embodiment of **Fig. 1**, thermal management controller **124** manages the thermal condition of light sources **102** based at least in part on the thermal condition indicated by the signals outputted by sensors **112**. Likewise, thermal management controller **124** may manage the thermal condition to achieve one or more of the earlier described system objectives.

Figure 3 illustrates a block diagram view of yet another projection engine/system in accordance with yet another embodiment of the present invention. Engine/system **300** is the union of engine/system **100** and engine/system **200**. That is, similar to engine/systems **100** and **200**, engine/system **300** comprises light sources **102**, light valve **104** and projection lens **106** optically coupled to each other, and sensors **112** thermally coupled to the light sources **102**, as earlier described. Likewise, engine/system **300** comprises thermal management controller **134** and processor **108** electrically coupled to sensor **112** and light sources/valve **102/104** respectively. Further, engine/system **300** comprises active cooling arrangement **116**, electrically coupled to thermal management controller **134**, which is also electrically coupled to the drive circuitry of light sources **102**.

For the embodiment, thermal management controller **134** is designed to manage the thermal condition of light sources **102** by selectively managing the amount of cooling imparted by active cooling arrangement **116** as well as the amounts of voltage or current applied by the drive circuit of light sources **102** to drive light sources **102**.

As the embodiments of **Fig. 1-2**, thermal management controller **134** may manage the thermal condition of light sources **102** based at least in part on the thermal condition indicated by the signals outputted by sensors **112**. Likewise, thermal

management controller **134** may manage the thermal condition to achieve one or more of the earlier described system objectives. Thermal management controller **134** may vary the operation of active cooling arrangement **116** and the drive circuitry of light sources **102** in tandem, or in succession.

Thus, it can be seen from the above description, a thermally managed projection engine/system has been described. While the present invention has been described in terms of the foregoing embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. Other embodiments may be practiced with modification and alteration within the spirit and scope of the appended claims. Accordingly, the description is to be regarded as illustrative instead of restrictive.